

FINAL REPORT:

NASA ISO grant NAG5-3411

**INFRARED SPACE OBSERVATORY (ISO) KEY PROJECT:
THE BIRTH AND DEATH OF PLANETS**

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Final Report, NAG5-3411,
Covering the period from inception, 9/1/96 thru end, 8/31/99
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Collaborators:

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(now at JPL, 9/99)

Dr. Sergio Fajardo-Acosta, Research Associate, University of Denver
(now at IPAC, 9/99)

Dr. Dana Backman, Franklin and Marshall College
(SIRTF Science Advisor)

PROGRESS SINCE THE INITIATION OF THIS GRANT:

This grant represented a transition between NASA Headquarters management of this ISO Key Projects, in the form of grant NAGW-3680 to the University of Denver (#5-34268), and the assumption of this role by JPL in 1998, again in the form of ISO grant JPL #961503 (DU#5-35134).

OBJECTIVES:

This program was designed to continue to analyze observations of stars thought to be forming protoplanets, using the European Space Agency's Infrared Space Observatory, ISO, as one of NASA Key Projects with ISO. A particular class of IRAS-discovered stars, known after the prototype, Vega, are principal targets for these observations aimed at examining the evidence for processes involved in forming, or failing to form, planetary systems around other stars.

In addition, this program continued to provide partial support for related science in the WIRE, SOFIA and SIRTF projects, plus approved ISO supplementary time observations under programs MCREE129 and VEGADMAP. Their goals include time dependent changes in SWS spectra of Long Period Variable stars and PHOT P32 mapping experiments of recognized protoplanetary disk candidate stars.

STATEMENTS OF WORK:

VEGADISn/VEGAMAIN: The Key Project effort, "ISO Observations of Circumstellar Disks, Clues to the Birth and Death of Planets" has amassed 315 total ISO observations through end of mission, April 1998, using PHOT (various AOTs), SWS and CAM, based on an originally awarded total of 35 hours of integration time. The observations are being systematically reduced, although calibration remains a major issue.

At the most recent AAS meeting (Austin, Jan.99), Fajardo, Stencel and Backman provided evidence based on ISO mapping in comparison with new sub-millimeter maps of two Vega-disk sources that a particle size segregation exists, placing the larger grains in tori near the traditional Kuiper belt inner boundary of ~ 50 AU, and smaller grains in an extended torus to the detection limit, beyond 100-200 AU. Standard theories cannot account for this differentiation, making it an important area for verification with newer facilities (SOFIA, SIRTf).

A paper describing spectral energy distributions of all of our ISO main sequence targets has been resubmitted to ApJ (main journal). We continue to explore with PHOT experts as to the cause of ISO vs IRAS calibration discrepancies. Our analysis indicates that based on PHOT PIA 6.1 level processing with drift correction, ISO fluxes are systematically fainter than IRAS at 11.5 microns by a factor of 3. To complete the color-color diagram analysis and the spectral energy distribution studies necessary to evaluate statistical frequency of infrared excesses associated with protoplanetary disk formation, it will be necessary to understand the ISOPHOT calibration in detail. Part of the resolution of this may rest in study of the MSX infrared catalog supposedly to be released this spring.

Another area where we anticipate prompt results is the effort to correlate the frequency of infrared excesses diagnostic of planetary processes, with the age of the stellar system involved. A graduate student who began this project, unexpectedly dropped out, and our intent is to involve new postdoctoral talent (as Sergio Fajardo is taking a job with the WIRE project at IPAC). The important task is based on these and related, newly-released ISO observations, combined with literature and spectroscopic determinations of stellar ages for our sample of stars.

MCREE129: This ISO program was awarded 28.8 kiloseconds of observing time to pursue SWS full spectrum observations of long period variable stars at several pulsational phases during their cyclic variation. The goal involves determining the detailed spectroscopic changes expected in the 10 micron silicate feature, plus ancillary longer wave features, during the pulsational cycle. IRAS LRS observations and others have suggested this is to be expected, and ISO can make definitive measurements about this phenomenon in advance of SIRTf. Variations will define the astrochemistry of circumstellar dust formation, the physics of stellar winds and the quantity and composition of matter returned to the interstellar medium that foments the next generation of stars in galaxies. As the attached information indicates, over 21 observations have been accomplished as of early March 1998, including several repeat observation of the same star at new phases.

VEGADMAP: This ISO program VEGADMAP was allocated 9200 sec. of priority 2 time, and 8900 sec. of priority 3 time. It consists of oversampled PHOT P32-C100 60 micron maps of ten Vega-type systems. With this imaging survey we want to find out: (1) How frequently Vega-type stars show resolvable extended structures of cool dust, at about 100 AU from the stars; (2) For those systems with definite extended emission, we want to infer the geometry of the circumstellar dust distribution. Our observing sample consists of bright (total 60 micron flux greater than 0.5 Jansky) nearby (closer than 20 parsecs) Vega-type main-sequence stars. IRAS photometry of these sources show far-infrared excesses, but there are no IRAS spatially-resolved measurements for the majority of these systems. Hence, ISO maps will provide crucial information in preparation of future SIRTf observations. As the attached information indicates, over 10 observations have been accomplished as of end of mission.

With the success of ISO in its operational phase, much of our effort came to fruition. ISO depleted its cryogens during spring of 1998, ending the observational phase. The work continues under a new grant from JPL in 1999, following no cost extension of this one. However, since this document will never be read, I want to offer a substantial reward to any civil servant who actually discovers this line of text prior to Jan. 1, 2000. In the event SIRTf launches on the current 2002 schedule, we will provide data to assist its investigators.

ONGOING: analysis of ISO observations using analysis tools PIA (PHOT), IDL software for CAM and SWS while waiting for suitable tools to become exportable and correlating results with characteristics of targets, using IRSKY, DSS and other database tools and observations. This work is being supported in '99/'00 under ISO Key Project funding managed by JPL.

Continuing during all mission phases:

- evaluate on-orbit performance and react to required modifications
- analysis of data as obtained for patterns and trends
- examine calibration and software updates per data results
- if possible, fine tune data entry for balance of observing program
- make use of any opportunity to propose additional targets
- support of ancillary programs (e.g. ground based observations needed)

New:

- (1) Standard theories cannot account for the now observed differentiation in particle sizes with distance from the central star, making it an important area for re-examination in numerical simulations, newly-released ISO data, and verification with newer facilities (SOFIA, SIRTf).
- (2) Part of the resolution of ISO vs IRAS calibration issues may rest in study of the MSX infrared catalog supposedly to be released soon.
- (3) An important task, based on our survey plus related, newly-released ISO observations, combined with literature and spectroscopic determinations, involves deriving stellar ages and abundances for our sample of stars.

Earlier activities are included in previous annual reports submitted to NASA HQ (ISO K.P. Program, started as NAGW-3680). Circumstances have caused this program to change grant management centers since the early 1990s.

PUBLICATIONS CITING NASA ISO SUPPORT
(NAGW-3680/NAG5-3411/JPL980901)

"ISO Photometric Search of Main-Sequence Stars for Vega-type Systems"
S.Fajardo-Acosta, R.Stencel, N.Thankur and D.Backman
1999 Astrophys. Journal vol. 520, pp.215-223.

"ISO and sub-mm Imaging of Dusty Disks around Vega-like Stars"
S.Fajardo-Acosta, R.Stencel, N.Thankur and D.Backman
1998 Bulletin of the Amer. Astron. Soc. (Austin, 1/99) vol. 30, p.1350.

"ISO Spectral Energy Distributions of Vega-type stars"
S.Fajardo-Acosta, R.Stencel, N.Thankur and D.Backman
1998 June Protostars and Planets IV meeting, Santa Barbara (poster).

"The ages of Vega-type stars in an ISO survey"
N.Thankur, S.Fajardo-Acosta, R.Stencel and D.Backman
1998 June Protostars and Planets IV meeting, Santa Barbara (poster).

"ISO Spectral Energy Distributions for Vega-type Stars"
N.Thakur, S.Fajardo-Acosta and R.Stencel
1998 BAAS (poster 47.13, Jan 1998 Washington DC AAS meeting).

"The Near Infrared Spectrum of the beta Pictoris Disk"
S. Fajardo-Acosta and D.Backman
1998 BAAS (poster 47.05, Jan 1998 Washington DC AAS meeting).

"ISO Mapping of 60 micron Dust Emission Around Vega-type Stars"
S.Fajardo-Acosta, R.Stencel & D. Backman
1997 Astrophys.Journal (Letters) vol. 487, pp. L151-L154, and also 1997
BAAS 28, p.1300.

"The Birth and Death of Planetary Systems" R.E.Stencel & D.E.Backman, ISO
1996 Special Session, Madison AAS meeting 6/96 BAAS 28, p.902

"First Results from NASA Key Project VEGADISK" R.Stencel, Invited talk
1996 May ESTEC meeting "First Results from ISO"

"A Model of Kuiper Belt Small Grain Population and Resulting Far-IR
Emission"

D.E.Backman, A.Dasgupta and R.E.Stencel
1995 Astrophysical Journal (Letters), Vol. 450, pp. L35-38

"Source-Sink Equilibrium Model for Kuiper Belt Small Grain Population,
and Far-IR Search in COBE DIRBE Data"

A.Dasgupta, D.E.Backman and R.E.Stencel
1995, B.A.A.S. 26: 1376 (Tucson).

“ISO-NASA Key Project: The Birth and Death of Planetary Systems”

R.E.Stencel and D.E.Backman

1994 B.A.A.S. 26: 884 (Minneapolis)

“Infrared Colors of Main Sequence Stars: How Much Circumstellar Debris is Normal?”

R.E.Stencel,

1995 in Circumstellar Matter 1994, G.D.Watt and P.M.Williams, eds.,
(Astrophys. & Space Sci. vol. 224), Kluwer-Dordrecht, p.401

“The Beta Pictoris Phenomenon”

D.E.Backman and R.E.Stencel,

1994 July IAU Symposium (abstract).

“Planetary System Evolution and the Vega Stars: Observations Possible with ESA’s Infrared Space Observatory”

R.E.Stencel and D.E.Backman

1994 Astrophysics and Space Science 212: 417-422.

“Additional Spectroscopic Discoveries Possible Among Stars with ISO”

R.E.Stencel,

1993 in Proceedings, Conference on Infrared Astronomical Spectroscopy, ed. S.Kwok, ASP Conf. Ser. Vol. 41, pp.113-114.

(end of report)